The Importance and Relevance of Meteorite Collection and Curation to Meteoritic Research – Past, Present and Future.

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Introduction:

Meteorites are some of the rarest, most precious and valuable geological materials available for scientific study, thus the curation of these important materials is of critical importance. Meteorite curation covers the care and management of the physical specimen but importantly, also covers the recording and archiving of many types of information related to individual specimens, such as recovery and collection, sub-sampling and use of the specimens and details of results or specific analyses undertaken.

The birth of meteorite curation and research - the 18th and 19th centuries:

Prior to the late 18th century meteorites were considered to be little worthy of scientific study and very few specimens have been preserved. Two notable exceptions are the Nogata meteorite, which fell 19th May, 861 and the Ensisheim meteorite, which fell 7th November, 1492. The recovery and preservation of these samples is very unusual and solely down to the circumstances and locations of their falls; the Nogata meteorite falling close to a Shinto shrine and the Ensisheim meteorite falling at a time of great political turmoil in that region of Europe [1,2]. The modern science of meteoritics and meteorite curation can be considered as beginning in the 1760s with the witnessed fall and recovery of the Albaretto and Lucé meteorites. Lucé is the first meteorite for which detailed eyewitness accounts of the fall were recorded and, importantly, the first sample to be chemically analyzed [3]. However, it was not until the last two decades of the 18th century that meteorites became the subject of sustained and detailed scientific scrutiny and even then their extraterrestrial origin was still doubted by many of the scientific elite of the time.

New opportunities for curation and research – the 20th century:

The 20th century saw tremendous technological advances in a wide variety of analytical techniques used to study meteorites, however the number of meteorites available for study was not increasing at a corresponding rate. Prior to the late 1960s there were approximately 2100 known meteorites curated in museum and university collections around the world and of these, approximately 40% were witnessed falls. The 1960s saw the start of dedicated fireball observation programs. These had the dual aims of gaining a better understanding of fireball phenomena and the potential for recovering meteorites from observed fireballs. Three programs operated in Canada, the United States and Europe with varying degrees of success and of the three the European network is the only one still operating [4-6].

1969 was an extremely important year for meteoritics. A “tantalizing” discovery of nine meteoritic stones in the Yamato Mountains region of Antarctica by the Japanese Antarctic Research Expedition heralded new strategies for meteorite collection and curation [7,8]. This fortuitous discovery led to the realization that Antarctica is an extremely fertile region for meteorite collection, owing to the favourable environmental conditions for sample preservation and concentration [9]. To date, just over 31,000 meteorites have been recovered from the Antarctic continent [10]. The same year, Apollo 11 astronauts returned the first Moon rocks to Earth. These priceless samples were sent to the Lunar Receiving Laboratory in Houston for initial characterization and curation. This laboratory was the first purpose built facility for the analysis and curation of extraterrestrial samples [11].

In the latter part of the 20th century it was recognized that hot desert regions were also favourable meteorite hunting grounds, with the dry environment preserving meteorites and the sparse vegetation aiding visual searching [12]. To date more than 10,000 meteorites have been recovered from hot deserts worldwide [10].

Meteorite curation today and tomorrow – challenges and opportunities:

‘The Curator’s Dilemma’: The ever increasing collection of meteorites and the accompanying scientific study of them have posed some interesting challenges for the scientific curatorial staff that care for and manage collections. There are, perhaps, three major challenges presently faced by meteorite curators: 1) *Maintaining access to the collection whilst preserving material for future generations*. Although modern analytical techniques allow for the analyses of relatively small samples and sub-samples, the major meteorite collections are receiving increasing numbers of requests for material from researchers. Careful consideration of each loan request is a necessity to ensure the most appropriate samples are being allocated for each research project. In some circumstances it is not possible to fulfill requests for samples, which can lead to tensions between curators and researchers. 2) *Protecting the collection from damage/contamination whilst*

maintaining access. Rapidly recovered fall meteorites and those collected in Antarctica are considered to be the least contaminated of all samples and so are most appropriate for the majority of scientific investigations. Storage and handling of samples will always add a risk of contamination, however careful curatorial practice can minimize this risk, through the use of appropriate storage materials and environments and the recording of curatorial actions. 3) *Acquiring new specimens for the collection whilst competing in a commercial market and fulfilling legal/ethical requirements*. Collections that curate non-Antarctic meteorites are dependent on acquiring meteorites through field collecting, exchanging with other institutions or through purchase/exchange with commercial dealers and collectors. Meteorite falls, which are often the most scientifically relevant owing to the lack of contamination, have high monetary values as do rare or particularly unusual meteorite types. With limited resources it may only be possible to acquire very small amounts of particularly interesting specimens, which is problematic as these are the most requested samples. Some countries have laws that prohibit the removal of meteorites without the required permits so ensuring that specimens have not been illegally or illicitly removed is also significant issue for consideration.

Sample return space missions and 'end to end curation': Since the Apollo missions, only three space missions have successfully collected extraterrestrial samples and returned them to Earth – NASA's Genesis mission (solar wind particles) and Stardust mission (cometary and interstellar particles) and JAXA's Hayabusa mission (asteroidal material). Over the coming decades a number of missions are programmed, or are in the planning stages, to visit Solar System bodies and return samples. NASA's OSIRIS-Rex, JAXA's Hayabusa 2 and ESA's MarcoPolo-R are all asteroid sample return missions and there are early-stage proposals for missions to visit Phobos, Mars and the Moon. A major driver for all these sample return missions is to provide the international scientific community with samples that are uncontaminated by terrestrial materials, which otherwise could compromise various science results, for example detection of organic molecules of astrobiological significance.

Whilst it is obvious that samples will need to be curated once they are returned to Earth, curation also plays a critical part in the planning stages of sample return missions. For example, in the same way that meteorite samples are carefully collected during Antarctic field work, samples collected by 'robotic geologists' will also require careful collection and handling to prevent possible contamination and damage to the sample. Similarly, how the samples are stored for return to Earth is also important. Storage vessels need to be designed so that the samples are protected during transit and landing on Earth and made from materials that are inert and un-reactive to the specimens they contain. Once the samples are received in the curation facility the prime concern is to retain their scientific integrity. Thus, they need to be stored under stringent environmental conditions e.g. ultra clean, inert atmosphere or under vacuum, and for Mars samples in a biologically sterile environment. These will be some of the most desirable samples available for study and so the curation facility must also be able to prepare samples for study and then manage and track the movement and use of samples by the scientific community. Thus, curation of sample return samples should be considered as 'end to end' – curation is a critical element from the first stages of mission planning to the long-term care and management of samples for perhaps many decades post-return.

Concluding remarks:

Since the birth of meteoritics as a scientific discipline in the late 18th century, collection, curation and research have progressed hand in hand. The increasing numbers of meteorites collected and the developments in a wide variety of analytical techniques used to study them has necessitated a close, but occasionally tense, relationship between scientific curators and researchers. Meteorite curation and research continue to support each other through a 'virtuous circle' of well-curated and appropriate materials supporting internationally significant research. This in turn supports and justifies both the continuing existence of collections and the enhancement of them though the acquisition of new samples. Technologies developed and experience gained in the curation of meteorites, cosmic dust, Apollo, Genesis, Stardust and Hayabusa samples has provided a solid foundation of knowledge and experience of how to successfully curate some of the rarest specimens on Earth. International teams are applying this curatorial legacy in planning for the next phases of Solar System exploration through sample return space missions.

References:

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